Twisted crystals point way toward active optical materials

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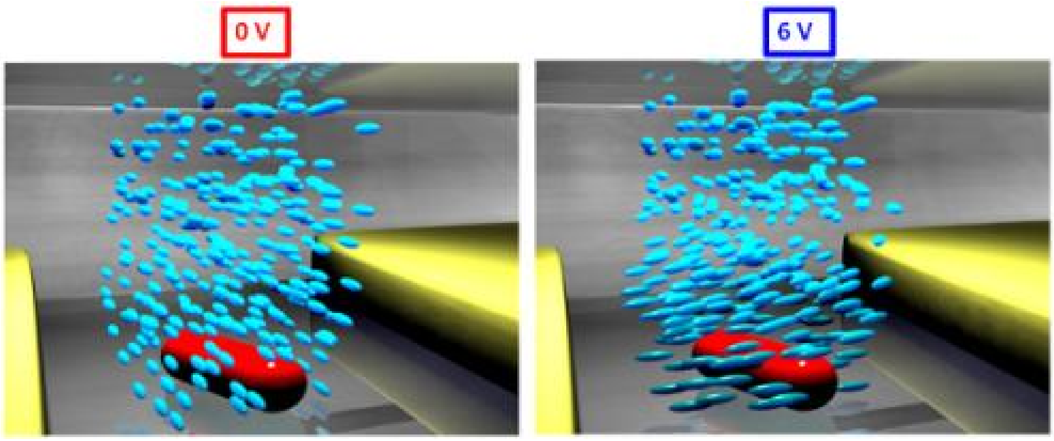


Applied voltage creates a nematic twist in liquid crystals (blue) around a nanorod (red) between two electrodes in an experiment at Rice University. This graphic shows liquid crystals in their homogenous phase (left) and twisted nematic phase (right). Depending on the orientation of the nanorods, the liquid crystals will either reveal or mask light when voltage is applied. (Credit Link Lab/Rice University)

(PhysOrg.com) -- A nanoscale game of "now you see it, now you don't" may contribute to the creation of metamaterials with useful optical properties that can be actively controlled, according to scientists at Rice University.

A Rice laboratory led by chemist Stephan Link has discovered a way to use liquid crystals to control light scattered from gold nanorods. The researchers use voltage to sensitively manipulate the alignment of liquid crystal molecules that alternately block and reveal light from the particles; the gold nanorods collect and retransmit light in a specific direction.

The research was reported in the American Chemical Society journal Nano Letters.

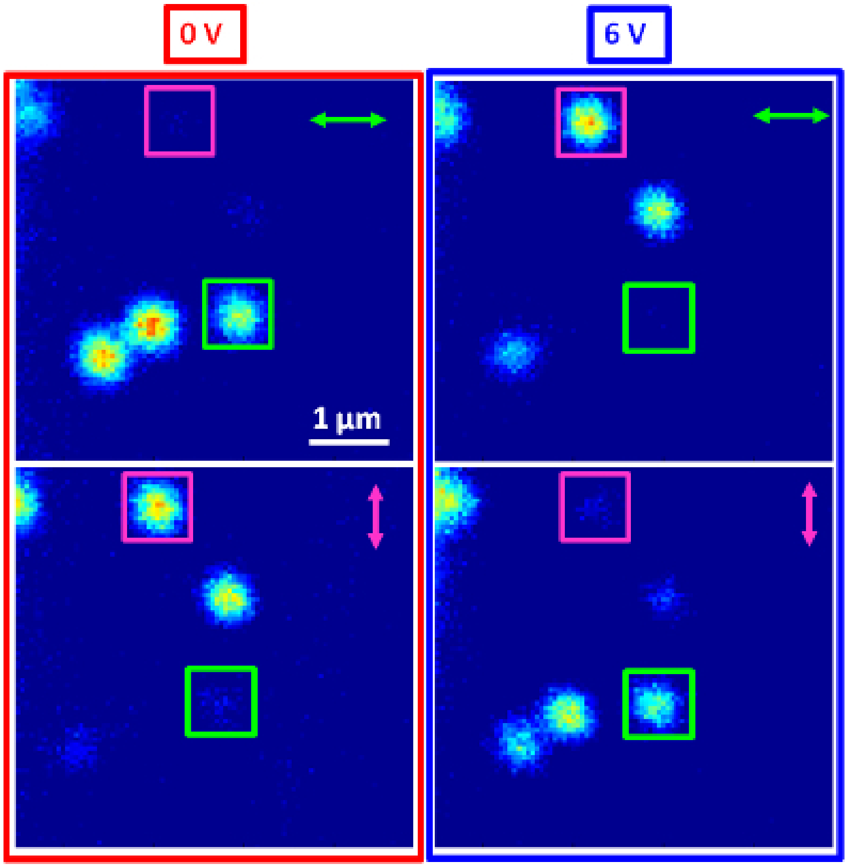
It seems simple, but Link said the technique took two years to refine to the point where light from the nanoparticles could be completely controlled.

"The key to our approach is the in-plane rotation of liquid crystal molecules covering individual gold nanorods that act as optical antennas," said Link, an assistant professor of chemistry and electrical and computer engineering. "Learning how our devices work was exciting and has provided us with many ideas of how to manipulate light at the nanoscale."

Link said the device is actually a super half wave plate, a refined version of a standard device that alters the polarization of light.

With the new device, the team expects to be able to control light from any nanostructure that scatters, absorbs or emits light, even quantum dots or carbon nanotubes. "The light only has to be polarized for this to work," said Link, who studies the plasmonic properties of nanoparticles and recently authored a perspective on his group's recent research in plasmonics for the Journal of Physical Chemistry Letters. (View a video of Link and his team here.)

In polarized light, like sunlight reflecting off water, the light's waves are aligned in a particular plane. By changing the direction of their alignment, liquid crystals can tunably block or filter light.



Polarized dark field scattering images of single gold nanorods in electrode gaps show them either turned on or off depending on voltage applied to a swarm of liquid crystals. The arrows indicate the polarization of detected light, either parallel (purple) or perpendicular (green) to the electrode array. (Credit Link Lab/Rice University)

The Rice team used gold nanorods as their polarized light source. The rods act as optical antennas; when illuminated, their surface plasmons re-emit light in a specific direction.

In their experiment, the team placed randomly deposited nanorods in an array of alternating electrodes on a glass slide; they added a liquid crystal bath and a cover slip. A polyimide coating on the top cover slip forced the liquid crystals to orient themselves parallel with the electrodes.

Liquid crystals in this homogenous phase blocked light from nanorods turned one way, while letting light from nanorods pointed another way pass through a polarizer to the detector.

What happened then was remarkable. When the team applied as little as four volts to the electrodes, liquid crystals floating in the vicinity of the nanorods aligned themselves with the electric field between the electrodes while crystals above the electrodes, still under the influence of the cover slip coating, stayed put.

The new configuration of the crystals -- called a twisted nematic phase -- acted like a shutter that switched the nanorods' signals like a traffic light.

"We don't think this effect depends on the gold nanorods," Link said. "We could have other nano objects that react with light in a polarized way, and then we could modulate their intensity. It becomes a tunable polarizer."

Critical to the experiment's success was the gap – in the neighborhood of 14 microns -- between the top of the electrodes and the bottom of the cover slip. "The thickness of this gap determines the amount of rotation," Link said. "Because we created the twisted nematic in-plane and have a certain thickness, we always get 90-degree rotation. That's what makes it a super half wave plate."

Link sees great potential for the technique when used with an array of nanoparticles oriented in specific directions, in which each particle would be completely controllable, like a switch.

More information: pubs.acs.org/doi/abs/10.1021/nl201876r

Provided by Rice University